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# Is there a shortage of scientists? A re-analysis of supply for the UK

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## **Abstract**

Despite a recent economic downturn, there is considerable political and industry pressure to retain or even grow the number of scientists in the UK and other developed countries. Claims are made that the supply of scientists (including engineers and mathematicians) is crucial to the economy and the health of the nation, and a large number of initiatives have been funded to address the problem. We consider these claims in light of a re-analysis of existing figures from 1986 to 2009, for young scientists passing through education and into employment. Science graduates are heavily stratified by social origin, and this sorting takes place during initial schooling just as it does with other ‘prestige’ subjects. The majority of science graduates then move into initial occupations that are not directly related to their degree, suggesting that at this stage of life at least, the demand for scientists trained in specific areas is more than met by existing numbers. We have no reason to believe that the situation is different to other vocational and non-vocational subjects, so perhaps science is not as special as politicians and business leaders imagine. Perhaps young people are put off careers in science by their education. Or perhaps the incentives are not right, leading to the ‘wrong’ kinds of students in science, and so wastage and inefficiency in the supply process. More pertinently, perhaps this vocational outcome is not how a developed country should assess the value and importance of scientific knowledge among its population.

Keywords:

science education

participation

policy

## Introduction

This paper provides a summary of a series of our recent research projects looking at the educational trajectories of prospective science, technology, engineering and mathematics (STEM) professionals in the UK (sometimes the figures are for England). It is based on existing evidence for hundreds of thousands of individuals each year, which allows us to examine patterns of participation in STEM education in a series of snapshots across the educational life course – from compulsory schooling through to when STEM graduates first enter the workforce. The work upon which this paper draws has examined recent historical as well as current trends, and looked across social groups as well as different educational phases. It has not been presented together in this form previously, and this analysis represents the most complete account yet of participation along the STEM pipeline – from school science to early STEM careers. The findings are presented in life order, beginning with education up to the age of 16, post-compulsory secondary education, higher education participation, and finally the first career destinations of STEM graduates. First, we rehearse some of the official concerns about the supply of STEM graduates, describe some of the measures taken to increase supply, and present a brief overview of the data and methods used in this paper. The paper ends by considering the implications for the supply of STEM professionals in the UK and suggesting some further areas for investigation.

### **A shortage of scientists**

Science, engineering and technology are the foundation for innovation and technological advance, and are traditional strengths of the UK economy. But skills shortages will threaten businesses capacity for growth unless action is taken now (CBI, 2010, p.2).

In an economy and a society with increasing demands for scientific and technological based goods and skills, a shortage of appropriately skilled workers is, according to many commentators, a threat to our ‘productivity, competitive position and level of innovation’ (Greenfield et al 2002:27, see also Zalevski and Kirkup 2009). Improving the recruitment, retention and training of the next generation of STEM professionals remains an area of

political priority and concern in the UK. Falling levels of engagement in STEM subjects at local and international levels is a problem which is well rehearsed and appears to persist across administrations. Its roots are considered to be in the poor quality of public education in the sciences, the high levels of dropout from science courses at university, poor pay and career prospects for STEM workers in comparison with other professions, and a failure to respond to the changing demands of an increasingly globalised STEM market (for example, Butz *et al.* 2006, Seymour and Hewitt 1997, Prados 1998). Indeed, according to a recent survey by the British CBI, one third of employers report shortages of graduates and 42% claimed that graduates lack the appropriate skills (CBI 2008). Similar surveys by the Sector Skills Council and other organisations also point to skills shortages among graduates across STEM areas (DIU 2009). These shortages are particularly evident for female STEM employees who experience higher levels of attrition than males at different stages along the STEM pipeline (Harding 2009, see also Author 2012).

Despite an increase in the number of people who study at Higher Education level in the UK, and current estimates place it at 43% of the 18-30 age group (Attwood 2010), it is still the case that inequalities persist with regard to who participates and who does not. Previous research in this area suggests that in most contexts the most important barrier to participation in HE is prior attainment (Raffe *et al.* 2006, see also Broecke and Hamed 2008, Galindo-Rueda *et al.* 2004, NAO 2008). But given that success in education is predicated on success at the previous educational stage (Gorard *et al.* 2007) and as young people from less affluent social groups achieve at lower levels throughout schooling, it is perhaps unsurprising that entry to HE is also stratified by social characteristics such as occupational class background and economic activity. The influence of the socio-cultural environment on participation in STEM subjects is an additional potential barrier to HE participation among under-represented groups. While traditionally much of the literature in this field has focused on the experiences of female STEM entrants (for example Ceci *et al.* 2009), research also points to the socio-cultural barriers faced by students from other non-traditional backgrounds (for example, Hurtado *et al.* 2009, Seymour and Hewitt 1997, Wynarczyk and Hale 2009, see also Gorard *et al.* 2007).

Concerns over STEM recruitment are not confined to the UK; they are also reflected in the STEM policies and in the post-compulsory education participation data of other developed nations. In 2000, EU leaders emerged from the Lisbon summit to declare their intention to

make the EU ‘the most competitive and dynamic knowledge-based economy in the world, capable of sustainable economic growth with more and better jobs and greater social cohesion’ (Lisbon European Council 2000). In Barcelona two years later, they called for an increase in R&D expenditure to around 3% of GDP by 2010 (Barcelona European Council 2002) and in 2005 with the mid-term review of the Lisbon agreement, the focus remained on filling the technology gap, supporting knowledge and innovation and strengthening the industrial base (Council of European Union 2005). These apparent shortfalls in the number of STEM professionals in Europe point to a need to increase human resources to levels commensurate with those in Japan and the USA: in other words to produce more scientists (for example Gago *et al.* 2004).

Interestingly however, from its own perspective the USA has its version of the ‘science problem’. In 2004, 32% of first degrees from US Higher Education institutions were awarded in STEM subjects, compared with 56% in China (National Science Foundation 2008). In part to compensate for lower levels of engagement among the US-born population, the proportion of ‘foreign-born’ scientists and engineers in the USA has grown rapidly in the last thirty or so years (National Academy of Sciences, 2007). The contribution of these international STEM workers to the advancement of US science has been very important; over one third of US Nobel Laureates are foreign-born. However their numbers have decreased post 9/11 (National Science Foundation 2008) leading to concerns that the US will lose out in the global marketplace for the best STEM students and scholars. Emerging economies such as India and China, who might once have exported their best STEM doctoral students to the USA, have increased their investment in scientific research and development as well as in Higher Education and appear to be ‘closing the gap’ in scientific publishing output and in the production of doctoral students; developments which are considered to present to the US a ‘troubling bellwether about [our] competitive position in the global science community’ (National Academy of Sciences, 2007:78).

### **Strategies to increase STEM recruitment**

One consequence of the perceived failure of the UK to adequately recruit, train and retain the next generation of professional scientists has been huge government investment in the sector. In 2004, for example, the STEM Mapping Review (DCFS 2006) revealed over 470 STEM

initiatives run by government departments and external agencies. All were designed to engage young people, and in particular underrepresented groups, in STEM subjects. The political commitment to make 'Britain the best country in the world in which to be a scientist' (Brown, 2009) has been continued. The new Coalition Government whose plans for the Comprehensive Spending Review ensured that Science and Research investment would be ring fenced and that the cost of supporting students studying STEM subjects in Higher Education would be maintained (Willetts 2010, BIS 2010). STEM subjects occupy a privileged position in UK government HE policy. They have an enhanced status as 'strategically important and vulnerable' (HEFCE, 2008) subjects and in the context of planned funding cuts to the HE sector in England, they are the key area which has been identified by the previous Labour government as well as the current Coalition Government for 'enhanced support' (DIU 2009:45). This means that whereas other subject areas will see a reduction in the number of funded places for students, money will be diverted to STEM courses 'which meet strategic skill needs' (DIU 2009:45).

This focus on the need to increase the supply of young people into the field is apparent in the number of initiatives and policies which, either directly or indirectly, seek to enhance participation in STEM areas. The motivations behind such initiatives are largely economic and represent industry's concerns for a suitably skilled workforce (CBI, 2008), particularly in the face of competition from other established and emerging economies, such as India and China (Society of Chemical Industry, 2006; Leitch Review of Skills, 2006). Many of these strategies focus on teaching and learning and in particular the nature of the school science curriculum (Author 2010). Indeed, from the Nuffield Science programmes of the 1960s, to the GCSE double science award at the end of the 1980s thence to Curriculum 2000 and the Twenty First Century Science programme, there have been continued attempts to improve the school science curriculum. Its critics continue to perceive it to be unapproachable and unappealing (Roberts 2002:72). In the UK during the early 1980s the 'problem' of girls and science received widespread attention and contributed to initiatives such as the Girls into Science and Technology (GIST) (Smail et al. 1982) and the Women into Science Engineering (WISE) campaigns (WISE 2007). Both of these had the broad aim of increasing the numbers of women who follow careers in STEM subjects. These and similar programmes were based on the premise that girls were not participating in science and that their subsequent lack of qualifications in this area would preclude them from most technical jobs, as well as leaving many women 'technologically illiterate and at a distinct disadvantage in modern society'

(Smail et al. 1982:620). Perhaps due to lack of consensus over why certain groups remain under-represented in many parts of the STEM field, it is an area which continues to attract a great deal of investment and attention. In this paper, we look at the impact that many decades of initiatives and programmes to increase the participation of young people in STEM education have had on recruitment to the field.

## **Methods**

The school-age data summarised in this paper comes from the pupil-level annual schools census (PLASC) and National pupil database (NPD) in England, for 2005/06. The age cohort consists of around 650,000 pupils. The Key Stage 4 (age 16) pupil results used here for all subjects combined and sciences are based on GCSE points. In 2005/06, an A\* grade at GCSE was considered worth 58 points, a C grade 40, and a G grade 16. The points are capped in the sense that they represent the total of the best eight scores at GCSE, or GCSE equivalents. The figures for maths and English are based on the percentage attaining at least grade C or equivalent in GCSE. Unfortunately, from 2005 the NPD discontinued the point scores for maths and English. This means that the figures are not directly comparable to those for science. The Key Stage 5 (age 18) pupil results are QCA points based on A-level scores and equivalents, including vocational qualifications. For example, an A grade at A-level is counted as 270 points and the lowest pass at E grade as 150 points. The other variable used is eligibility for free school meals (FSM) which is an indicator of pupil family socio-economic background, applied to a pupil in a family with an income deemed to be living below the poverty line (Hobbs and Vignoles 2010). Scores are shown as averages broken down by sex, FSM, and curriculum area. Further details, other key stages, more years of data, and some discussion of limitations in the data, appear in Gorard and See (2008).

Data on applications and admissions to university in the UK, broken down by sex, subject, and year, come from UCAS and the HESA Individualised Student Records (ISRs). For more on these, and their potential and limitations, see Gorard (2008).

Using data from the annual graduate destination survey (which is collected by the Higher Education Statistical Agency), it is possible to gain an understanding of the sorts of careers that are open to STEM graduates after they have left university in the UK. The HESA first destination survey gathers information on the activities of graduates six months after they

graduate. Response rates tend to be relatively high; for the Physical Sciences they are over 80%. Previous work suggests that non-responders are at least as likely to be in employment or further study as respondents. This dataset only considers destinations at six months after the student has left university, and it is recognised that career trajectories may be very different in the subsequent period. However, it tells us a great deal about the sorts of jobs that are immediately available to science graduates.

## Participation and attainment in school science

At present, England has a system in which science, as narrowly defined, is a core subject from primary stage onwards. Participation itself is not an issue while science is a core subject at school. Statutory tests at age 7, 11 and 14 have shown that attainment in science is stratified by pupil background. Pupils from poorer areas, or who are eligible for free school meals, have considerably lower average test scores (Gorard and See 2008). Similarly, there are clear differences in overall attainment in sciences at age 16 between students of differing backgrounds (e.g. Table 1). However, these differences are no larger, and often smaller, than the differences for all subjects. Whatever the problem is, leading to the differential attainment of social, ethnic and economic groups, it is certainly not one that is specific to science. The general patterns are the same as for science. Maths is like science in having only a very small difference between scores for boys and girls and so is unlike English. The gaps between ethnic groups are also large but based on very small numbers for the minority groups. Therefore, perhaps the most worrying gap in all these subjects is between students eligible and not eligible for free school meals (FSM). But again these are not appreciably larger in science, so perhaps SES is not the problem for science attainment that some commentators believe.

Table 1 - Mean capped points scores (all subjects and sciences) and percentage attaining grade C or above (maths and English), all students, KS4, England, 2005/2006.

	All subjects	Science subjects	Grade C+ maths (%)	Grade C+ English (%)
Male	338	33	50	49
Female	378	34	52	64



Non-FSM	373	35	55	61
FSM	266	25	27	31
Overall	359	34	52	58

Source: NPD/PLASC.

Once students are faced with a choice of how to study science (usually at around age 14 in England) or whether to study science at all (usually post-16), there is a dropping off of participation, especially in physics and chemistry. Most pupils, given the chance, do not study the ‘hard’ sciences. This is not a new phenomenon and there is no evidence that it has worsened over the last decade.

### **Participation in post compulsory science programmes: A-levels**

The drop-off in study of hard sciences is stratified to some extent by SES measures, which also relate to prior attainment. In general, students are not encouraged to continue with science unless they have been relatively successful in previous stages. Those taking maths or science in any combination after age 16 have, on average, higher prior attainment scores than students other taking A-levels or equivalent (Table 2). Perhaps their attainment at A-level (or Key Stage 5) is therefore partly based on talent, as shown by their prior score, and so deserved, rather than necessarily being based on relative privilege and so undeserved (Rawls, 1971). This situation is not unique to science.

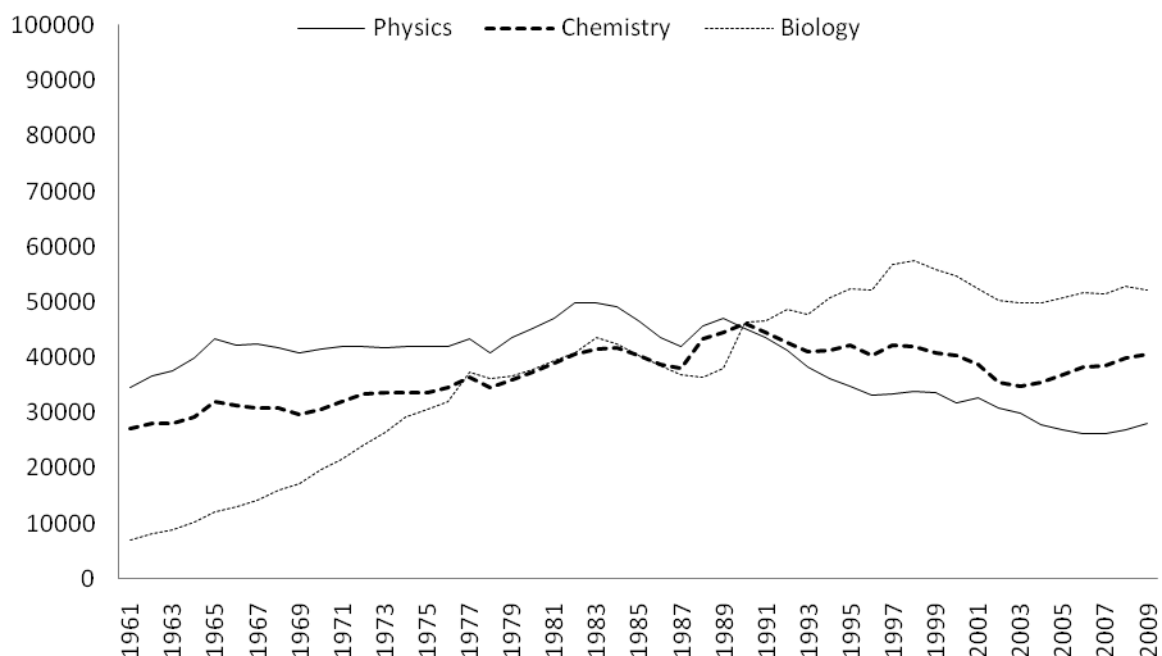
Table 2 - Prior and post-attainment points scores, KS5, all entrants, England, 2005/2006.

	Mean total prior attainment score (KS4 points)	Mean total post attainment score (QCA points)
Science	484	844
Not science	427	663
Maths	487	925
Not maths	434	674
Science or maths	482	848
Neither science nor maths	424	648

Source: NPD/PLASC.

The number of young people continuing to post-16 education generally has risen since 1961 in the UK, but this has made little difference to the overall number taking physics, chemistry and biology (Figure 1). Instead the picture shows the sciences largely competing among themselves for approximately the same total of students each year. The number of young people studying physics was lower in 2009 than in 1961 but was compensated for, if that is the right term, by an increase in numbers studying biology.

Figure 1 - Participation in the pure sciences at A-level, number of candidates, 1961-2009



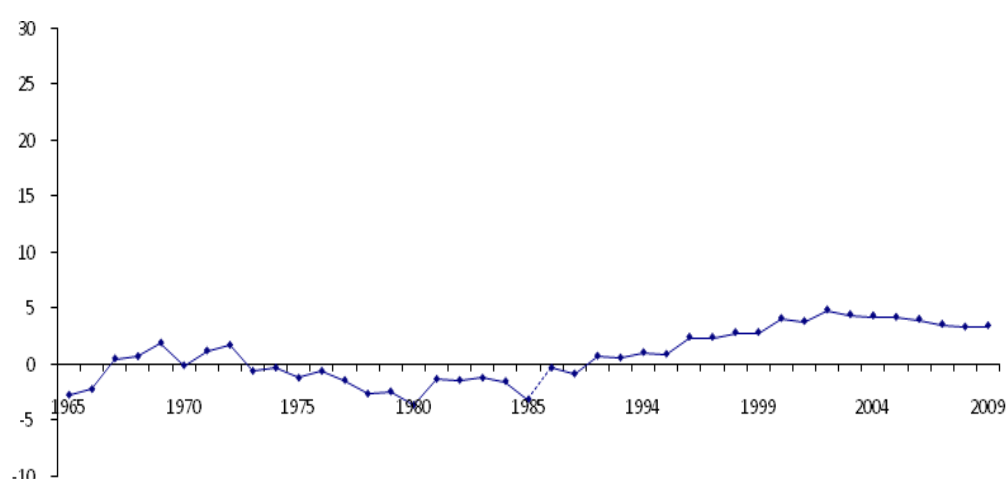
Source: DES, DfES, DCSF, QCA, JCQ, AQA, Edexcel, IoP

In physics, there are now fewer students studying the subject than in the early 1960s, with numbers in steady decline since the late 1980s, when physics (and the other sciences) became a core part of the National Curriculum in England and Wales. The figures for chemistry are higher than they were during the 1960s but recent decades have seen a plateau in the numbers studying the subject. Arguably biology is in the healthiest position of the three, but its numbers have also stabilised recently. One reason for the relatively healthy position of biology is the large number of female students who opt to study the subject. In 2009, there were almost 30,000 female biology candidates (60% of the cohort), physics on the other hand

has seen little change to the proportion of candidates who are female. In 2009 around 6000 females studied the subject at A-level, a similar number to those in the mid 1960s (Author 2011). This stability in the female participation figures comes despite initiatives such as GIST and WISE that focus on encouraging girls to study physics after the age of 16. There is nothing to suggest that these initiatives have had a positive effect on recruitment.

The extent to which academic achievement at A-level can be considered to be an explanation of gendered participation in STEM subjects at the next academic level is questioned by the figures in Figure 2. What this analysis shows is that the achievement gap between the sexes in the “pure” sciences has hardly varied over the last five decades, providing no evidence that male students have ever consistently outperformed females at this level. In physics, there has been some slight shifting of the achievement gap in favour of female candidates since the mid-1990s. However, any gender gap in the attainment of candidates is negligible and overall it can be said that attainment at the higher grade levels in physics is gender neutral. This provides no evidence to suggest that attainment in the sciences is a barrier to female participation at the next level. The gap is no larger than the general gender gap in all subjects (Gorard et al. 2001).

Figure 2 - Achievement gaps between male and female A-level physics candidates 1965-2009



Source: DES, DfES, DCSF, QCA, JCQ, AQA, Edexcel, IoP

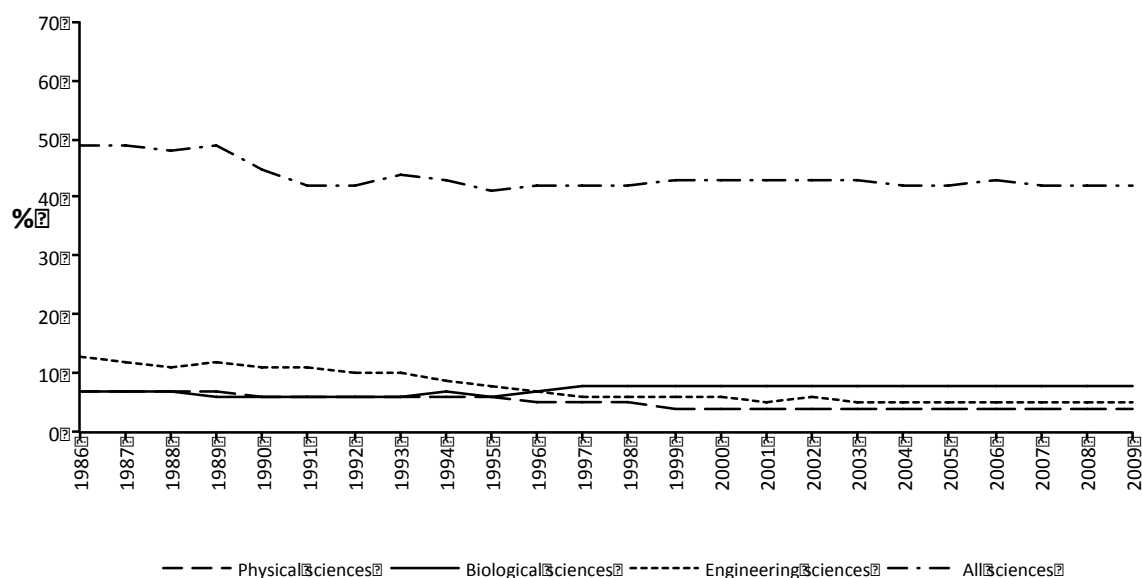
Note: Students achieving grades A-C. A positive value indicates overall higher achievement among female candidates. Values of less than 4% are not considered to represent a noticeable gap (Gorard et al. 2001).

This analysis of long-term patterns of participation shows that none of the three science A-level subjects has grown as post-16 participation has grown more generally. In physics, fewer male students are studying the subject now than in the early 1960s, while female numbers have never really changed. In chemistry, numbers have varied little in a decade and in biology, traditionally seen as the “healthiest” of the pure sciences, numbers also appear to have reached a plateau.

### **Participation in undergraduate science programmes**

The share of candidates who then apply to study science and science-related subjects at UK universities remains similarly stable over time. The same applies to admissions as well, certainly since the early 1990s (Figure 3). Indeed, just less than half of all students who apply through UCAS do so in order to study the sciences, reduced slightly over the last twenty years or so, despite a considerable rise in overall numbers. There is little evidence here of a major ‘swing’ away from science subjects, since there are slightly more science students now than ever before. Science subjects overall, but the individual ‘hard’ sciences, have almost kept up with the rapid increase in the number of students studying at university.

Figure 3 - Acceptances to selected science subject groups, as a percentage of all acceptances, 1986-2009



Note: The organisation of UCAS STEM subject groups is provided in the Appendix

Table 3 compares the relative success of candidates in being offered places to study science subjects in HE over a 15 year period. This is expressed as the percentage of applicants who were offered places. An asterisk denotes subjects where more students were accepted to courses than originally applied. This is, in part, likely to be a consequence of them being offered places through the UCAS clearing system. Clearing is a service which is offered by UCAS to help people without a university place to find a suitable vacancy or who have not secured their preferred course to find alternatives. It runs annually from July to September after the usual period of recruitment has ended. Although \* represents more than 100%, it is not a healthy sign for any course or subject to go to clearing, and the more prestigious UK universities avoid it for that reason. One noticeable difference between the acceptance rate for all candidates in 1994 and 2009 is that applicants are now generally more likely to be offered places in HE than previously. And this is especially so for the sciences (with near or over 100% acceptance rates).

Table 3 - Percentage of applicants who are accepted to selected STEM degree programmes

	1994	1998	2000	2003	2006	2009
Biological Sciences	76	79	85	88	95	93

Psychology	61	78	87	82	89	89
Biology	95	94	96	*	*	*
Physical Sciences	91	*	*	*	*	*
Chemistry	*	*	*	*	*	*
Physics	91	89	91	92	93	95
Mathematics	*	*	*	*	97	93
Computer science	91	92	86	93	98	*
Engineering Sciences	94	*	*	*	*	*
All Sciences	83	94	97	*	98	96
All Subjects	69	76	79	81	80	78

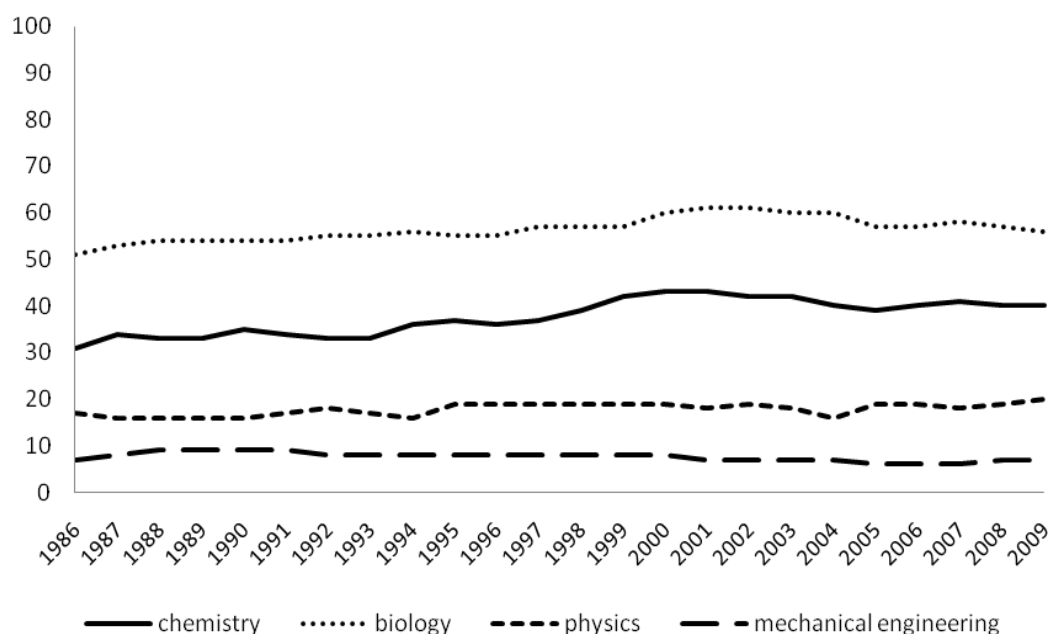
Source: UCAS/HESA

This change from 1994 to 2000 onwards might be interpreted in several ways. It could be a sign that HE in the UK has become more equitable, enabling bright students from a range of backgrounds to secure a place at university which previously they would have been denied. An alternative explanation is that in the rush to expand HE provision, entry standards have fallen and it is now easier to secure a place on a degree course which would once have been reserved only for the more able students. However, there is no evidence to suggest that science candidates are any less well qualified than others or previously, in terms of A-level and equivalent qualifications. Indeed, in 2009 72% of candidates accepted to the Physical Sciences had achieved at least A-level grades BBB or equivalent, compared with 57% across all subjects. In the eight years since UCAS started assigning qualification tariff points in 2002 (to establish equivalences between different types of qualifications) the trend has been towards higher entry grades, across all subjects (Author 2011). A discussion of variations in A-level standards over time is beyond the scope of this paper, but Coe et al. (2008) point to a clear indication that science A-levels are generally harder than those in other subjects. So we have an interesting paradox of science as a subject area which is seen as being an important contributor to the nation's economic prosperity being offered additional student places. And yet science more than most subjects is apparently struggling to recruit for the places it has already (we see later whether it can provide relevant employment for its graduates).

As at A-level, initiatives like GIST and WISE appear to have made little impact on the proportion of women who are studying these traditionally male subjects at HE undergraduate

level (Figure 4, see also Author 2012). So for example, in 1986 around 7% of mechanical engineering undergraduates were female. In 2009, the proportion was the same.

Figure 4 - Percentage of female candidates accepted to the largest-recruiting science subjects, selected years 1986-2009.

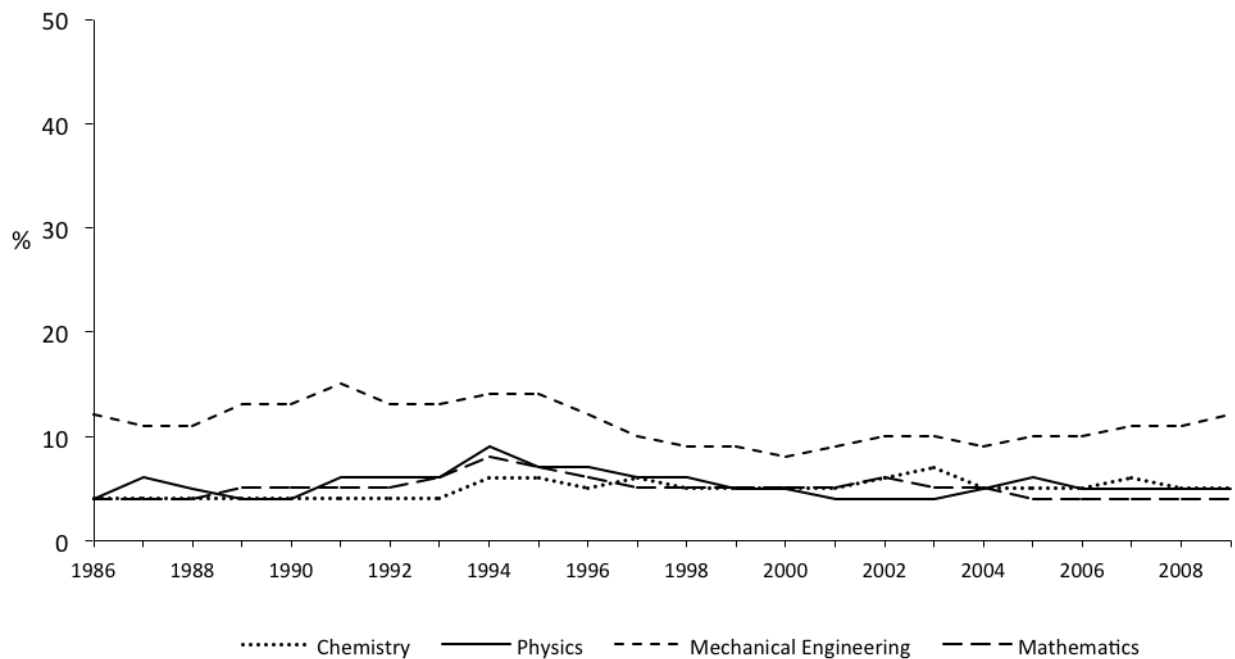


Source: UCAS/HESA

Another key area of WP initiatives, age, is also one in which inequalities in science recruitment appear to persist despite the high acceptance rates for existing applicants. In the late 1980s and into the early 1990s there was a slight rise in the proportion of non-traditional aged applicants who were accepted to study in HE. This coincided with the expansion of the polytechnic sector, which was ‘newly removed from the control of the local authorities and immediately responsive to the quasi-market mechanisms introduced at this time’ (Parry 2006, p. 395). With their partnerships with the Further Education colleges, Access qualifications and implicit widening participation agendas, the polytechnics were at the vanguard of what became a period of ‘exponential growth’ in the HE sector during the late 1980s and early 1990s. Because polytechnics traditionally recruited a larger proportion of ‘mature’ entrants, this was reflected in a larger number of older students being accepted onto science degrees during that period. However, such growth, particularly in the STEM subjects was not sustained. As Figure 5 shows, the proportions of non-traditional aged students entering key STEM subjects have hardly changed over the past two decades. In chemistry, physics and

mathematics, for example, the figures have varied by only a few percentage points in almost 25 years and remain consistently low at around 6% of the cohort. Mechanical engineering has fared slightly better than these other three subjects but levels of non-traditional aged participation have not followed a consistent pattern, with levels of recruitment in 2009 comparable to those in 1986.

Figure 5 - Non-traditional aged acceptances as a percentage of all acceptances, selected individual STEM subjects 1986-2009



Source: UCAS/HESA

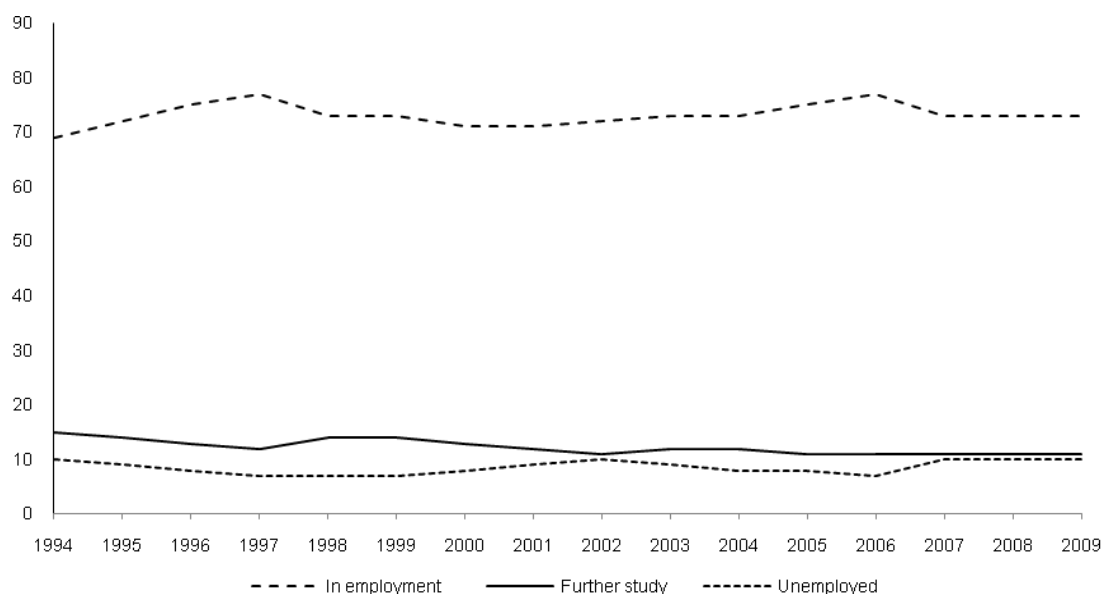


Similar stability is found in the participation figures for ethnic and social groups (Author 2011), however monitoring the relative participation of these groups in comparison to the non-participating population is problematic (Gorard 2008).

### Patterns of employment among newly qualified STEM graduates

On leaving university, the patterns of first employment for STEM subjects are all similar, with relatively low levels of unemployment. We focus here on engineering science as this has the highest proportion in employment, making an analysis of the *kinds* of employment (below) more fruitful. A higher proportion of recent graduates in maths and the physical sciences tend to continue to further study, which is mostly initial training as teachers. In the UK, the national curriculum emphasises science and maths for all, partly on the basis that these subjects are important for the employment reasons given above. But the national curriculum then demands that many graduates train as teachers to teach the next generation (Gorard et al. 2006). Figure 6 shows the broad range of activities undertaken by all recent graduates in the Engineering Sciences between 1994 and 2009. Most graduates enter some form of employment, 15% continue to further immediate study, and around 10% are unemployed. The patterns have remained stable over the past fifteen years.

Figure 6 - First destinations of Engineering Science graduates, 1994-2009



Source: HESA

A more detailed description of the type of employment undertaken by engineering graduates is provided in Table 4 (using the most recent year, and 2003 for comparison). The pattern in all years is similar. In general, less than half of all graduates who report an occupation are in employment directly related to their degree. Even though this is only the first destination survey after six months, it is astonishing in light of claims of science graduate shortages that so few new graduates go into related employment. Of the rest, just under a quarter of newly qualified engineers report every year that they are working in what are considered to be non-graduate jobs, including in unskilled and routine employment, such as being cashiers and waiters. Around 10% are in general management and a further 10% are classified as ‘other’. It is unlikely that such a high proportion each year would prefer such employment long-term and the figures suggest that it is not easy or automatic for qualified engineers to get related employment in the UK, despite the purported shortages.

Table 4 - Percentage of recent Engineering Science graduates in each occupation, 2003 and 2009

Occupation	2003	2009
<i>Employment directly related to degree subject</i>		
ICT professionals (213)	5	4
Research professionals (232)	1	1
Science professionals (211)	0.3	0.4
Science/Engineering technicians (311)	3	2
Engineering professionals (212)	34	38
IT Service Delivery Occupations 313	2	1
<i>Employment indirectly related to degree subject</i>		
Design Associate Professionals 342	2	2
Media Associate Professionals 343	1	2
Public service other associate profs (356)	1	1
Teaching professionals (231)	2	2
Business and statistical professionals (242)	1	2
Business and finance ass. professionals (353)	2	2
Architects, Town Planners, Surveyors (243)	1	1

All managers and senior officials (1)	10	8
<i>Non graduate employment</i>		
Sales and related associate professionals (354)	2	3
Elementary administration and service (920)	4	5
Sales occupations (710)	6	9
Customer service occupations (720)	2	2
General administrative (415)	3	2
Skilled metal and electrical trades (520)	1	1
Elementary trades (910)	2	1
Administrative Occupation Records (413)	3	1
Unknown	0.3	0.2
<i>Other</i>	11	9
N	7160	6500

Note: includes occupations which recruit at least 50 graduates (plus group 211 and unknown). Cases represent full-time, home domiciled, first degree students who enter employment only.

Perhaps, because of recent initiatives, there seem to be too many people studying science for the labour market to cope with, or perhaps graduates are no longer of sufficient quality. It is more likely however, that all of these scientists are without relevant employment every year because the shortage thesis is wrong and there are no jobs waiting for all of them, or because they are ‘dropping out’ having learnt that they do not enjoy their subject areas.

## Conclusion

This paper has considered patterns of participation and attainment in STEM-related education in the UK. It has examined the stages which take students from national tests at age 16, through A-level and undergraduate work and into employment or further study. As well as considering how aggregate levels of engagement vary at each educational stage, the research reported here has used the best available evidence to monitor participation and attainment over an extended period of time, particularly among some groups who are traditionally under-represented in STEM fields. The findings have shown that engagement in most STEM subjects is persistently stratified by ability and also by social characteristics. Indeed, it seems

that the long-standing stereotype of ‘science’ being a difficult subject studied by traditional age, middle-class, high-attaining men remains.

Whereas UK public spending has declined in real terms since the economic downturn of 2008 onwards, one area where policy-makers have claimed that spending has been sustained and even increased is the supply of new scientists (including technology, engineers and mathematicians or STEM). However the research presented here suggests that STEM graduates remain stratified by social origin and ability and that this sorting takes place during compulsory schooling, in the same way as it does for other high status subjects. If prior attainment in science (or indeed any subject) is used to determine future participation (and attainment), and because we know that SES and attainment are linked, then the situation we find is as expected. Science is seen as a hard subject post-16 and so whatever the benefits, human capital theory would predict a relatively low uptake. In addition, using a stratified and stratifying variable like qualification (ability, aptitude, attainment) to select students means that the student body will be stratified by SES. At age 16, the differences in attainment between social groups are no larger in science than in all subjects. But many other subjects do not require, or appear to require, such a high level of KS4 attainment in order to continue study.

Taken together the UK government’s proposals to develop the nation’s scientific skills base largely lie in increasing the *supply* of young people into the STEM professions either through attracting well qualified people into teaching, increasing the science content of the National Curriculum in schools or reforming the curriculum so as to encourage able young people to remain in the ‘science stream’ and subsequently study the subject at university. However, it seems apparent that decades of well-funded and well-targeted initiatives have had little (if any) impact and even requiring that all young people study the sciences up to the age of 16 has had limited long term effect on recruitment at the next educational levels. For example, students with the lowest attainment scores at age 16 (or none at all) continue to be less likely to continue with post-16 full-time study – whether of science or not. Changing the nature of opportunities available post-16 tends to have no impact on the non-participants. The total proportion of the 16-year-old cohort remaining in education, government schemes and employment-based training combined has remained constant for decades, even though the balance between routes varies according to the local history of funding and availability (Payne, 1998). Furthermore the proportion remaining in education and training continues to

be stratified in terms of social class, ethnicity and region (Denholm & Macleod, 2003). Since science is seen as a hard choice at A-level or equivalent, the most useful predictor of participation post-16 is again attainment at age 16, especially in science and maths. Mathematical and language skills are important predictors of science uptake (Uerz, et al., 2004). Traditional science, unlike psychology for example, is not taken as an additional new subject but as one in which the student has not failed before. To some extent this is a matter of choice, but it is also often a criterion imposed by schools and colleges. Either way, it leads to physical sciences being dominated by those with high GCSE-level attainment (Osborne et al., 2003) or equivalent (Uerz et al., 2004), which is in turn linked to high attainment at each previous Key Stage and to social class background. These are patterns which appear impervious to policy interventions, however wide ranging or well-intentioned.

So why have initiatives to increase participation in STEM subjects appeared to have limited impact? One possible explanation is that while the numbers of students remaining in post-compulsory education have increased these ‘new’ recruits are those who were never likely to study STEM subjects anyway. Students who would be likely to study physics or chemistry, which require relatively high entry grades and a commitment to the subject at age 16, would always have entered Higher Education and would have been largely unaffected by recent widening participation agendas or other initiatives to increase recruitment. It also appears that those who remain in the STEM pipeline throughout their education are unlikely to remain in the field after university either because they no longer enjoy the subject or the opportunities for employment are simply not there. Perhaps what is required is a more objective examination of the demands of the STEM sector for suitably qualified workers along the lines of that advocated by Teitelbaum (2003) and Lowell and Salzman (2007). This refocusing on demand rather than supply would go some way to answering the question posed in the title to this paper. Is there actually any shortage of scientists? It would also enable schools to focus on what many argue are the primary goals of science education: ‘to educate students both about the major explanations of the material world that science offers and about the way that science works’ (Osborne and Dillon 2008:8) rather than the current emphasis on preparing a minority of students to be the next generation of STEM professionals.

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## References

- Attwood, R (2010), Mind the gap, *Times Higher Education Supplement*, 26<sup>th</sup> February 2010, accessed February 2010  
[www.timeshighereducation.co.uk/story.asp?sectioncode=26&storycode=410531&c=2](http://www.timeshighereducation.co.uk/story.asp?sectioncode=26&storycode=410531&c=2)
- Barcelona European Council (2002), Presidency Conclusions, Barcelona European Council, 15<sup>th</sup> and 16<sup>th</sup> March 2002, accessed October 2008 from  
[http://www.fondazionecru.it/eracareers/documents/research\\_policy/Barcelona%20EUCouncil%202002.pdf](http://www.fondazionecru.it/eracareers/documents/research_policy/Barcelona%20EUCouncil%202002.pdf)
- BIS (2010), The Spending Review 2010, 20<sup>th</sup> October 2010, Department for Business, Innovation and Skills, accessed from  
<http://www.bis.gov.uk/news/topstories/2010/Oct/BIS-CSR>
- Broecke, S., Hamed, J., (2008), Gender Gaps in Higher Education Participation: An Analysis of the Relationship between Prior Attainment and Young Participation by Gender, Socio-Economic Class and Ethnicity, DIUS Research Report 08 14, accessed February 2010, from [http://www.dius.gov.uk/research\\_and\\_analysis/~media/publications/D/DIUS\\_RR\\_08\\_14](http://www.dius.gov.uk/research_and_analysis/~media/publications/D/DIUS_RR_08_14)
- Brown, G., (2009), The Romanes Lecture given at the Sheldonian Theatre Oxford, 27<sup>th</sup> February 2009, accessed May 2009 from [www.number10.gov/Page18472](http://www.number10.gov/Page18472)
- Butz, W.P., Bloom, G.A., Gross, M.E., Kelly, T.K., Kofner, A., Rippen, H.E., (2006), Is there a shortage of scientists and engineers? Issue Paper: Science and Technology, California: The RAND Corporation
- CBI (2008), *Taking stock: CBI Education and skills survey 2008*, London: CBI, accessed June 2009 from [http://www.cbi.org.uk/pdf/skills\\_report0408.pdf](http://www.cbi.org.uk/pdf/skills_report0408.pdf)
- CBI (2010), SET for growth: Business priorities for science, engineering and technology, accessed November 2010 from  
[http://highereducation.cbi.org.uk/uploaded/SET\\_for\\_growth.pdf](http://highereducation.cbi.org.uk/uploaded/SET_for_growth.pdf)
- Ceci, S., Williams, W., Barnett, S., (2009), Women's Underrepresentation in Science: Sociocultural and Biological Considerations, *Psychological Bulletin*, 135(2), pp218-261.
- Coe, R., Searle, J., Barmby, P., Jones, K., Higgins, S., (2008), Relative difficulty of

- examinations in different subjects, Report for SCORE, accessed May 2009 from [http://sv.iop.org/News/Community\\_News\\_Archive/2008/file\\_30371.doc](http://sv.iop.org/News/Community_News_Archive/2008/file_30371.doc)
- Council of European Union (2005), Presidency Conclusions, European Union Council Brussels 22<sup>nd</sup>-23<sup>rd</sup> March 2005, accessed October 2008 from [http://ue.eu.int/ueDocs/cms\\_Data/docs/pressdata/en/ec/84335.pdf](http://ue.eu.int/ueDocs/cms_Data/docs/pressdata/en/ec/84335.pdf)
- Denholm, J., & Macleod, D. (2003). *Prospects for growth in further education*. Somerset, UK: Learning and Skills Research Centre.
- Department for Children, Schools and Families (2006), The Science, Technology, Engineering, and Mathematics Programme Report, London: DCSF, accessed from <http://www.dcsf.gov.uk/hegateway/uploads/STEM%20Programme%20Report.pdf>
- DIU (2009), The Demand for Science, Technology, Engineering and Mathematics (STEM) Skills, accessed March 2010 [http://www.bis.gov.uk/assets/biscore/corporate/migrateddd/publications/d/demand\\_for\\_stem\\_kills.pdf](http://www.bis.gov.uk/assets/biscore/corporate/migrateddd/publications/d/demand_for_stem_kills.pdf)
- Gago, J., Ziman, J., Caro, P., Constantinou, C, Davies, G., Parchmann, I., Rannikmae, M., Sjoberg, S. (2004). *Increasing Human Resources for Science and Technology in Europe*, Report of the High Level Group on Human Resources for Science and Technology in Europe, Luxembourg, European Communities.
- Galindo-Rueda, F., Marcenaro-Gutierrez, O. and Vignoles, A. (2004). The Widening Socio-Economic Gap in Higher Education. *National Institute Economic Review*, 190 (1), pp. 75–88.
- Gorard, S., (2008). Who is missing from higher education? *Cambridge Journal of Education*, 38(3), pp421-437
- Gorard, S., G. Rees, and J. Salisbury. 2001. Investigating the patterns of differential attainment of boys and girls in school. *British Educational Research Journal* 27(2), pp125–39.
- Gorard, S., See, B.H., Smith, E., & White, P. (2006). *Teacher supply: The key issues*. London: Continuum.
- Gorard, S., Adnett, N., May, H., Slack, K., Smith, E., Thomas, L., (2007). *Overcoming the barriers to higher education*, Trentham Books.
- Gorard, S., See, B.H., (2009). The impact of socio-economic status on participation and attainment in science, *Studies in Science Education*, 45(1), pp93-129
- Greenfield, S., Peters, J., Lane, N., Rees, T., Samuels, G., (2002), A Report on Women in Science, Engineering , and Technology for the Secretary of State for Trade and Industry, Accessed March 2010 from [http://extra.shu.ac.uk/nrc/section\\_2/](http://extra.shu.ac.uk/nrc/section_2/)

- publications/reports/R1182\_SET\_Fair\_Report.pdf
- Harding, R., (2009), *Women's Enterprise and SET*, London: NPCWE.
- HEFCE (2008), *Strategically important and vulnerable subjects, Final report of the 2008 advisory group*, accessed April 2010 from [www.stemnet.org.uk/\\_db/\\_documents/strategic\\_subjects\\_final\\_report\\_08\\_20090323042053.pdf](http://www.stemnet.org.uk/_db/_documents/strategic_subjects_final_report_08_20090323042053.pdf)
- Hobbs, G., Vignoles, A., (2010), 'Is children's free school meal 'eligibility' a good proxy for family income?', *British Educational Research Journal*, 36(4), pp673-690.
- Hurtado, S., Cabrera, N.L., Lin, M.H., Arellano, L., Espinosa, L.L., (2009), Diversifying Science: Underrepresented Student Experiences in Structured Research Programs, *Research in Higher Education*, 50(2), pp189-214.
- Leitch Review of Skills, (2006), *Prosperity for all in the global economy - world class skills: Final Report*, London: HMSO.
- Lisbon European Council (2000), Presidency conclusions, Lisbon European Council, 23<sup>rd</sup> and 24<sup>th</sup> March 2000, accessed October 2008 from [http://ue.eu.int/ueDocs/cms\\_Data/docs/pressData/en/ec/00100-r1.en0.htm](http://ue.eu.int/ueDocs/cms_Data/docs/pressData/en/ec/00100-r1.en0.htm)
- Lowell, L., Salzman, H., (2007), *Into the Eye of the Storm: Assessing the Evidence on Science and Engineering Education, Quality and Workforce Demand*, Urban Institute, accessed May 2010 from <http://www.urban.org/publications/411562.html>
- National Academy of Sciences (2007), *Rising Above the Gathering Storm: Energizing and Employing America for a Brighter Economic Future*, accessed November 2009 [http://books.nap.edu/openbook.php?record\\_id=11463&page=86](http://books.nap.edu/openbook.php?record_id=11463&page=86)
- National Audit Office (2008) *Widening participation in higher education*, London: The Stationery Office, accessed February 2010 from [http://www.nao.org.uk/publications/0708/widening\\_participation\\_in\\_high.aspx](http://www.nao.org.uk/publications/0708/widening_participation_in_high.aspx)
- National Science Foundation (2008), *Science and Engineering Indicators*, accessed January 2010, from <http://www.nsf.gov/statistics/seind08/c2/c2s2.htm>
- Osborne, J., Dillon, J., (2008), *Science Education in Europe: Critical reflections*. A report to the Nuffield Foundation, London: Nuffield Foundation.
- Osborne, J., Simon, S., Collins, S., (2003), Attitudes towards science: A review of the literature and its implications. *International Journal of Science Education* 25, no. 9: 1049–79.
- Parry, G., (2006), Policy-Participation Trajectories in English Higher Education, *Higher Education Quarterly*, 60(4), pp 392–412.



- Prados, J.W., (1998), Engineering Education in the United States: Past, Present and Future, accessed December 2009 from [www.ineer.org/Events/ICEE1998/Icee/papers/255.pdf](http://www.ineer.org/Events/ICEE1998/Icee/papers/255.pdf)
- Raffe, D., Croxford, L., Iannelli, C., Shapira, M., Howieson, C., (2006), *Social-Class Inequalities in Education in England and Scotland*, Special CES Briefing No. 40 May 2006, Centre for Educational Sociology, accessed February 2010 from <http://www.ces.ed.ac.uk/PDF%20Files/Brief040.pdf>
- Rawls, J. (1971). *A theory of justice*. Oxford: Oxford University Press.
- Roberts, G., (2002), SET for Success: The study of people with science, technology engineering and mathematical skills, London: HMSO.
- Seymour, E., Hewitt, N.M., (1997), Talking about leaving: Why undergraduates leave the sciences, Colorado: Westview Press.
- Smail, B., Whyte, J., Kelly, A., (1982), Girls into science and technology: the first two years, *School Science Review*, June 1982, p620-629.
- Society of Chemical Industry (2006), *Strategic chemistry-based science education into the 21<sup>st</sup> Century, Paper 2*, London: SOCI Insight.
- Teitelbaum, M.S., (2003), Do we need more scientists? *The Public Interest*, Fall 2003, pp40-53.
- Uerz, D., Dekkers, H., & Beguin, A. (2004). Mathematics and language skills and the choice of science subjects in secondary education. *Educational Research and Evaluation*, 10(2), 163–182.
- Willetts, D., (2010), David Willetts, speech delivered to the HEFCE Annual Conference, Royal College of Physicians, London, 21<sup>st</sup> October 2010 accessed from <http://nds.coi.gov.uk/content/Detail.aspx?ReleaseID=416135&NewsAreaID=2>
- WISE (2007), Women into Science, Engineering and Construction, accessed December 2009 from <http://www.wisecampaign.org.uk/>
- Wynarczyk, P., Hale, S., (2009), *Improving Take up of Science and Technology Subjects in Schools and Colleges: A Synthesis Review Report* prepared for the Economic and Social Research Council “Science in Society” Team and the DCSF, accessed September 2010 from <http://tinyurl.com/39xqo8o>
- Zalevski, A., Kirkup, G., (2009), *The case for increasing gender diversity of company boards in SET, Policy Briefing No. 12*, Bradford: UK Resource Centre for Women in SET.